

## Comparative analysis of cutting fluids

I V Ershova<sup>1,2</sup>, N E Kalinina<sup>1</sup>, E V Cherepanova<sup>1</sup> and D F Fayskhanov<sup>1</sup>

<sup>1</sup> Institute of New Materials and Technologies, Ural Federal University named after the first President of Russia B N Yeltsin, 19, Mira street, Yekaterinburg, 620002, Russia

E-mail: <sup>2</sup>i.v.ershova@urfu.ru

**Abstract.** The article contains the results of seven working tests of cutting fluids for metal-cutting equipment. The results of the analysis were evaluated by experts, including process engineers, chemical engineers, foremen and production machine operators in the following areas: turning, drilling, milling, sawing, grinding, threading, boring works. The analysis made it possible to determine the scope of application of cutting fluids depending on the volume and rhythm of the work, the operating conditions of the cutting fluids, the requirements of the design and technological documentation taking into account the final cost of the cutting fluids used. The problem of determining an accelerated system of practical tests for cutting fluids to evaluate the effectiveness of using a particular product before conducting the production tests on machine equipment is considered. For this, criteria for evaluating the cutting fluids are proposed using the weighting method to ensure informed decision-making in the choice of a cutting fluid for admission to full-fledged production tests.

### 1. Introduction

Until now, the mechanical processing of parts and assembly units by the method of material removal: turning, milling, drilling, boring, planning, etc., remains the most widely used in the machine-building industry. Increasing the economic efficiency of these processes is a multifactorial and complex set of measures, including the machine productivity increase, the use of high-performance toolware, a set of measures to optimize the use of machine devices, and much more. All these factors are well studied, methods for assessing and improving the efficiency of production processes are developed. However, some factors, to which a unified assessment methodological approach has not yet been developed, still remain. One of these factors is the choice of cutting fluids (coolants) for use on metal cutting equipment. The situation becomes more complicated by the dynamically growing supply in the coolant market.

The main emphasis in the variety of products offered is the use of various coolant additives that improve its physicochemical properties. Additives are designed to qualitatively change the properties of the cutting fluid, changing its heat transfer, lubricating properties, resistance to bacterial damage, and other characteristics of material processing procedures to a given direction. Many experiments are conducted to identify improved qualities of cutting fluids using additives. The authors identify an effective decrease in temperature in the cutting zone and an increase in the quality of the machined surface [1], as well as an increase in the processing efficiency along with a decrease in the load on the spindle [2]. Other studies show an increase in tool life with improved morphology of the removed chips and improved roughness of the workpiece [3]. Abdelrazek A H, Choudhury I A, Nukman Y, Kazi S N conduct a comprehensive analysis of the stability and operational characteristics of various



types of coolants and lubricants and their impact on processing results and the environment [4]. The possibilities of minimizing the consumption of cutting fluids are being studied, which entails both a positive impact on the environmental component of production and on improving the quality of manufacturing parts [5]. The same trend is observed in the cutting fluids production of the domestic manufacturers, which confirms the effectiveness of the chosen direction of the consumer characteristics improving of the products offered. The use of additives in the production of domestic cutting fluids allowed them to effectively compete with foreign manufacturers, allowing them to increase the consumer properties of liquids, improve the physicochemical properties and environmental friendliness of the product. At the same time, it becomes very difficult to evaluate the entire range of coolants offered by the market and choose a product to recommend for use in production.

Technical and economic assessment of the cutting fluid is difficult due to the need to consider storage factors and allergic effects on workers, which is difficult to determine in cost terms. The company has to make a choice based either on the basis of recommendations from suppliers, or on the basis of coolant tests in the production process, or on the basis of price policy. It should be understood that none of these criteria provides a qualitative justification for the choice of a particular cutting fluid, because supplier recommendations are based on the suppliers' own economic objectives. Selection based on pricing policy can lead to the use of cheap, low-quality and toxic liquids, which will inevitably harm the health of workers, adversely affect the condition of equipment and tools, and also lead to a decrease in the quality of machining of parts and assembly units. Conducting tests in real production conditions, although it reflects the actual characteristics of the cutting fluid most effectively, has significant disadvantages: it requires high costs of time, materials and the coolant itself. Often in real production conditions it can be difficult to stop the equipment for complete system flushing from the coolant used, refilling with a new test fluid, and then conducting the actual tests, at the risk of obtaining poor-quality products or disabling the expensive equipment due to the use of poor-quality cutting fluid.

The study of scientific research has shown that different authors see different selection criteria. As a selection criterion, it is proposed to use the heat transfer coefficient [6], environmental criteria for coolant [7], assessment of cutting fluid by economic parameters in terms of the long-term operation price, taking into account environmental components [8]. To ensure the choice of a cutting fluid, as well as the possibility of determining their interchangeability, it is also proposed to formulate a detailed physico-chemical classifier of the available cutting fluids, which should provide a rational choice of a coolant [9], [10]. The most widespread among the researchers was the study of the lubricating properties of the cutting fluids [11–13], and cooling abilities [16] as the main selection criterion. Some aspects of the application of cutting fluids for the treatment of various metals are also investigated [16].

The purpose of the study is to develop a multifactorial methodology for the express evaluation of a cutting fluid, taking into account economic, technological and environmental factors.

## **2. Materials and methods**

The most common cutting fluid brands on the Russian market were selected as the objects of the study. To conduct an analysis of the cutting fluids presented, a group of specialists from the machine-building enterprise was involved in conducting tests in real production conditions to determine the most important evaluation criteria. The assessment group included: deputy chief technologist, deputy chief metallurgist, deputy chiefs (of the three workshops of the main production), 12 masters of machining areas, head of the central factory laboratory, 26 machine operators.

The first stage of the work was the selection of evaluation criteria. The ranking of the evaluation criteria was carried out by determining the ranks on a 10-point scale. Rank values were converted into the specific weight of the criterion according to its' importance. The list of evaluation criteria and their significance are given in table 1.

**Table 1.** Comparative characteristics of cutting fluids.

Name of criterion	Bechem Avantin 451	Bechem Avantin 361	IgatPlatinTopcol 2S	Quakercool 7200 BAF	Quakercool 7601 BFFR	Hosmarc RT11	Volgo 1320	Criterion weight
Price, RUB/kg	452.75	414.37	667.46	424.8	425	219.8	320	–
Washing properties	5	4	5	3	3	5	5	0.1
Foaming	5	5	5	4	5	4	5	0.125
Existence of allergic reactions	5	4	4	4	4	5	5	0.2
Rate of bacterial damage	5	5	5	4	4	5	5	0.125
Impact on tool wear	5	5	5	4	5	5	5	0.15
Cutting fluid consumption	5	4	5	3	4	4	4	0.15
Corrosive effect	5	4	4	4	4	5	5	0.15

Production tests of cutting fluids were carried out in machine-tool workshops using equipment for 4–6 months for each of the products. Each criterion was evaluated by experts independently on a 5-point scale. Agreed expert estimates rounded to integer values are given in Table 1.

Evaluation of the washing properties of the tested cutting fluid was carried out on the basis of observations of the condition of the working surfaces and protective covers of production equipment for the presence of soap sticks, mastic layers, greasing, and the degree of contamination.

The evaluation of foaming was carried out on the basis of observations of the cutting fluids tendency to produce foam.

The existence of allergic reactions was assessed by the presence of complaints from staff.

The rate of bacterial damage was estimated by the experience of long-term operation, including the assessment during prolonged standstill of equipment in the warm season.

Assessment of the impact on tool wear was evaluated based on the experience of equipment operation by workshop personnel.

Cutting fluid consumption was estimated by comparing the volumes to top up coolant in the equipment of the same type.

Assessment of the corrosive effect was carried out based on the appearance of the filter according to the degree of corrosion (0 points – strong, 5 points – no corrosion).

### 3. Results

The proposed assessment model is based on the calculation of the cutting fluid unit cost. For each cutting fluid, the total expert score was calculated according to the formula:

$$X = \sum(K_i \times y_i), \quad (1)$$

where  $K_i$  is the score of the  $i^{\text{th}}$  criterion,  $y_i$  is the weight coefficient of the  $i^{\text{th}}$  criterion.

The final cutting fluid assessment was carried out according to the unit cost criterion, calculated as the ratio of the price to the total score. The calculation is made for two options. In the first variant all criteria were taken into account, in the second variant the criterion ‘rate of bacterial damage’ was excluded, since during rhythmic work and large volumes of processing it is not significant. The calculation results are given in table 2.

**Table 2.** Cutting fluid unit cost

Indicator	BechemAvantin 451	BechemAvantin 361	IgatPlatinTopcol 2S	Quakercol 7200 BAF	Quakercol 7601 BFFR	Hosmarc RT11	Volgo 1320
1st option							
Total score	5	4.4	4.65	3.75	4.175	4.725	4.85
Unit cost	90.55	94.175	143.53	113.28	101.79	46.51	65.98
2nd option							
Total score	4.375	3.775	4.025	3.25	3.675	4.1	4.225
Unit cost	103.48	109.77	165.83	130.71	115.65	53.61	75.74

By assessing the unit cost of the estimated cutting fluid, we see that the Hosmarc RT11 product proved to be the most effective and can be further recommended for industrial use at the enterprise.

The significance of the criteria may vary depending on the requirements of a particular production process, which will affect the choice of the cutting fluid. Changes in prices will also lead to changes in estimates. This does not affect the assessment methodology.

The proposed express-evaluation methodology can be used by enterprises without testing in real production conditions and eliminating equipment downtime due to flushing of the coolant system and refilling with a new fluid.

## References

- [1] Duc T M and Long T T 2020 Effectiveness of alumina nanofluid on slotting end milling performance of SKD 11 tool steel *Journal of Computational and Applied Research in Mechanical Engineering* **9** 2 pp 359–369
- [2] Peña-Parás L, Maldonado-Cortés D, Rodríguez-Villalobos M, Romero-Cantú A G and Montemayor O E 2020 Enhancing tool life, and reducing power consumption and surface roughness in milling processes by nanolubricants and laser surface texturing *Journal of Cleaner Production* **253** 119836
- [3] Yıldırım Ç V 2020 Investigation of hard turning performance of eco-friendly cooling strategies: Cryogenic cooling and nanofluid based MQL *Tribology International* **144** pp 106–27
- [4] Abdelrazek A H, Choudhury I A, Nukman Y and Kazi S N 2020 Metal cutting lubricants and cutting tools: a review on the performance improvement and sustainability assessment *International Journal of Advanced Manufacturing Technology* **106** 9–10 pp 4221–45
- [5] Lopes J C, Garcia M V, Volpato R S, de Mello H J, Ribeiro F S F, de Angelo Sanchez L E, de Oliveira Rocha K, Neto L D, Aguiar P R and Bianchi E C 2020 Application of MQL technique using TiO<sub>2</sub> nanoparticles compared to MQL simultaneous to the grinding wheel cleaning jet *International Journal of Advanced Manufacturing Technology* **106** 5–6 pp 2205–18
- [6] Kisel A G, Rechenko D S, Titov Yu V, Purtov E D and Petrov I V 2015 Selection of cutting fluid for finishing *Omsk Scientific Bulletin Ser. Devices, machines and technologies* **3** (27) pp 39–43
- [7] Chernat I S 2016 Significant factors in the selection of cutting process fluids in mechanical engineering *Engineering industry and life safety* **1** pp 68–70
- [8] Zenkin N V, Varichkin I A and Sorokin S P 2016 Analysis of cutting fluids *Scientific almanac* **4–3** (18) pp 82–5
- [9] Kireynov A V and Esov V B 2017 Current trends in the use of cutting lubricants for blade processing of hard-to-process materials *Engineering Journal: Science and Innovation* **2**
- [10] Debnath S, Reddy M M and Yi Q S 2014 Environmental friendly cutting fluids and cooling techniques in machining: A Review *Journal of Cleaner Production* **83** pp 33–47
- [11] Sholom V Yu, Korshunov A A, Tyulenev D G, Trofimov A S and Kramer O L 2011 The results

- of laboratory and pilot tests of highly effective coolants for blade and abrasive processing operations *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences* vol **13 4 (3)** pp 913–7
- [12] Cherepakhin A A, Vinogradov V M and Smirnova E E 2008 Choice of coolant for high-speed pulling of external shaped surfaces *Assembly in mechanical engineering, instrument making* **9** pp 37–41
- [13] Kirsanov S V, Chekantseva L V and Tsygankov R S 2017 Choice of coolant for the operation of drilling deep holes with gun drills on multioperational machines *Reference. Engineering Journal with the application* **11** pp 3–9
- [14] Pozhidaev Yu A et al 2015 Choice of coolant for various cutting methods and machining conditions *Innovations in metalworking: a look of young specialists* pp 304–7
- [15] Kisel A G, Purtov E D and Deylova A V 2017 Assessment of the cooling properties of cutting fluids *Omsk Scientific Bulletin* **1 (151)** pp 27–9
- [16] Suleymanov R I and Suleymanov R R 2018 The effect of mechanically structured cells on surface quality in the processing of aluminum bronzes *Scientific notes of the Crimean Engineering and Pedagogical University* **4 (62)** pp 206–12